

6. BOLTING

6.1 Specifications

6.1.1 Bolting Material

The Contract Documents should specify the material for bolted connections. Production and inspection for all fastener material should be specified to conform to the latest editions of the American Society for Testing and Materials (ASTM) *Specifications*. High-strength bolts should conform to ASTM A325, A490, F1852 (twist-off bolt), or other bolt specifications as permitted for use in the American Institute of Steel Construction (AISC) and Research Council for Structural Connections (RCSC) *Specifications*. Nuts should meet either ASTM A563 or A194. Washers should meet ASTM F436. Direct tension indicators, if used, should meet ASTM F959.

6.1.2 Installation Requirements

All bolts and fastener assemblies should be installed in accordance with the requirements of the RCSC *Specifications*.

6.2 Submittals

6.2.1 Material Certifications

The Contract Documents should require the submittal of certifications for all bolting material, including bolts, nuts and washers. The manufacturer's certifications should state that the bolts, washers, nuts or other fastener components meet the applicable ASTM *Specification*. Certification of fastener material by the fastener component manufacturer is also a requirement of the ASTM *Specifications*. Certifications should be provided for each production lot of fastener component, with the exception that shipping lot certification is permitted for A490 bolts. The acceptance of shipping lot certifications for other fastener components is discouraged. Copies of certifications should be provided to the appropriate Inspector for review and use.

6.2.2 Bolting Installation Procedures

The Contract Documents should require the submittal of written procedures for the pre-installation testing, installation and pretensioning of high-strength bolts on the project. The procedures must meet the requirements of the RCSC *Specification*. Procedures need be submitted only for the methods of installation being used by the Fabricator and Erector, which may include the turn-of-nut, calibrated wrench, twist-off bolt, or direct tension indicator methods. Procedures should include both installation to the snug tight condition and pretensioned installation. Bolting procedures must also be distributed to the Inspector responsible for bolting inspection.

6.2.3 Bolting Inspection Procedures

The Contract Documents and Quality Assurance Plan should require the submittal of written inspection procedures for bolted installations. Such procedures must meet the requirements of the RCSC *Specification*. Inspection procedures should be written specifically for the installation and

pretensioning methods to be used, i.e. turn-of-nut, calibrated wrench, twist-off bolt, or direct tension indicator method. Written procedures should also be prepared for the arbitration of disputes, to be used should a dispute arise regarding the pretension of previously installed fasteners.

6.3 Material Controls

The Contract Documents should establish requirements for fastener material control, if control beyond type or lot is required. To verify the material suitability and installation procedures, the RCSC *Specification* requires pre-installation testing of each lot, or combinations of lots as used, prior to installation in the work. No records need be maintained regarding source or lot of individual fastener material once installed.

6.4 Quality Control and Quality Assurance

6.4.1 Extent of Bolting Inspection

The Quality Assurance Plan should contain a list of all required bolting inspections and should designate the responsible party. Such inspection may be provided by the Contractor, by the Special Inspector, or by a designated Bolting Inspector.

Bolted joints require verification of the quality of the holes, visual inspection by observation of the pre-installation tests and the tightening operations, and if a slip-critical joint is specified, the observation of the condition of the faying surface. The use of torque for random testing of installed bolts is not required and is discouraged.

6.4.2 Bolting Quality Control Program

The Contractor's Quality Control program for bolting should, as a minimum, include the following.

- Manufacturer's certifications are reviewed for adequacy and compliance with project requirements.
- Manufacturer's certifications are kept on file.
- A proper protected storage area is provided for all fasteners.
- A suitable material control system, including lot control, is in use.
- A bolt calibration device, calibrated within the past year, is available.
- Written bolting procedures are provided for the installation methods to be used.
- The bolting crew must know the selected bolting installation procedures.
- Bolting Inspectors must be trained and knowledgeable.

6.5 Bolt Installer Qualification

All personnel installing and pretensioning high-strength bolts should have the necessary knowledge and skills to perform the task. Verifying adequate knowledge of the installer provides a high level of confidence that the correct material will be selected and installed, that the snug condition will be achieved, and that the selected pretensioning method will be properly applied. The bolt installer qualification program should reduce the time and effort spent in bolt inspection, and reduce or eliminate the need for arbitration inspection.

Personnel responsible for installing bolts should possess, as a minimum, the following knowledge:

- bolt and nut grade identification,
- bolt length measurement,
- required lubrication conditions,
- the use of field bolt lists,
- the assessment of the snug tight condition, and
- the proper techniques for performing the selected pretensioning method.

For the turn-of-nut method, required knowledge includes determining the required rotation beyond the snug condition, proper match-marking techniques, and wrench observation techniques. For the calibrated wrench method, required knowledge includes the methods of wrench calibration, requirements for recalibration of wrenches, and the proper use of the calibrated wrench. For twist-off bolts, the required knowledge includes the use of the electric wrench for snugging, and the use of the wrench for pretensioning. For the direct tension indicator (DTI) method, required knowledge includes the placement of the DTI in the assembly, the use of feeler gages to check the snug condition, and the use of feeler gages to verify the pretensioned condition.

Bolt installer qualification testing should be performed through verbal or written questions on the above topics asked by the inspector, appropriate for the bolt pretensioning method selected for use. The installer should also perform three pre-installation verification tests for the method selected, witnessed by the inspector. Upon completion of this bolt installer qualification testing, the bolt installation personnel may proceed to install, snug, and pretension bolts on the project. Bolt installer qualification testing does not waive requirements for bolt installation inspection.

6.6 Bolting Inspection Tasks

The Bolting Inspector should coordinate the inspection work closely with the Contractor and other Inspectors. The Bolting Inspector(s) must perform all inspections required by the Contract Documents, the Quality Assurance Plan, the RCSC *Specification*, and the Building Code. Bolting inspection should be performed in a timely manner, so as not to hinder production, and to detect

bolting problems upon or soon after occurrence so that corrective measures may be taken by the Contractor to rectify such problems.

The duties of the Bolting Inspector, whether designated either QC or QA, should include the following items:

- a. Review and understand the applicable portions of the specifications, contract drawings, shop detail drawings and erection plans for the project.
- b. Review all manufacturer certifications for material compliance with the project requirements. (Refer to Figure 6-1)
- c. Verify bolting material identification. (Refer to Figure 6-1)
- d. Verify suitable, controlled storage conditions. (Refer to Figure 6-1)
- e. Verify that all applicable bolt installation procedures are available, current and accurate.
- f. Verify that all bolt installers are qualified (Refer to Figure 6-2)
- g. Verify that the appropriate bolt installation procedure has been provided and reviewed by each bolting crew member performing the work. (Refer to Figure 6-2)
- h. Observe the Contractor's pre-installation testing performed at the start of the work for each assembly lot. (Refer to Figure 6-3)
- i. For the calibrated wrench method of installation, observe calibration of the wrench(s) at the start of each work shift. (Refer to Figure 6-4)
- j. Verify the suitability of the bolted joints, such as bolt hole size and condition, prior to assembly. Check for unfair reaming or slotting of poorly aligned holes. (Refer to Figure 6-4)
- k. For slip-critical joints, verify that the required faying surface conditions are met. (Refer to Figure 6-4)
- l. Prior to pretensioning, verify that all bolts have been installed and the joint brought to the snug tight condition.
- m. For pretensioned joints, routinely observe, at suitable intervals, the pretensioning operations to verify the proper application of the bolting procedures. (Refer to Figure 6-4)
- n. Arbitrate any disputes regarding achieved bolt pretension immediately upon installation of the bolts in dispute. Any appreciable delay in arbitration will result in considerable inaccuracies in the arbitration procedures provided by the *RCSC Specification*. (Refer to Figure 6-4)
- o. Complete a written report recording the joints observed, inspected, and accepted. The report should be transmitted to the designated recipients in a timely manner. (Refer to Figure 6-4)

Bolting Material Inspection Record

(See Sections 6.6 b, c, d)

Project _____

Inspector _____

Date of Inspection ____/____/____

Complete this inspection log for each type of fastener product, diameter, length, grade and production lot for the fasteners to be used on the project.

Bolt

☐ A325 ☐ A490 ☐ A307 ☐ _____

Twist-Off Bolt

☐ F1852 ☐ Marked A325 ☐ Marked A490

Nut

☐ A563 grade _____ ☐ A194 grade _____

Washer

☐ F436

Direct Tension Indicator (DTI)

☐ F959 ☐ Type 325 ☐ Type 490

Manufacturer's mark and name _____

Diameter

1/2 5/8 3/4 7/8 1 1-1/8 1-1/4 1-3/8 1-1/2 _____

Length _____

Finish

- ☐ Black
- ☐ Hot dip galvanized
- ☐ Mechanically galvanized
- ☐ Epoxy coated
- ☐ Other

Lot Number _____

Figure 6-1 Bolting Material Inspection Record

Bolting Material Inspection Record

Container type

- ☐ Steel keg
- ☐ Wood keg
- ☐ Cardboard box
- ☐ Other
- ☐ Manufacturer's container
- ☐ Repackaged container

Storage conditions

- ☐ Protected
- ☐ Exposed

Lubrication condition

- ☐ Oily
- ☐ Dry
- ☐ Rusty
- ☐ Manufacturer coating
- ☐ Mixed
- ☐ Relubricated using _____

- ☐ **Certification reviewed** Date ____/____/____

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Figure 6-1 Bolting Material Inspection Record (continued)

Bolt Installer Qualification

(See Sections 6.5 and 6.6 f and g)

Bolt Installer Name _____ ID Number _____

	Bolt Installation Method			
	Turn-of-Nut	Calibrated Wrench	Twist-Off Bolt	Direct Tension Indicator
	Verification of Knowledge	Inspector _____ Date ____/____/____	Inspector _____ Date ____/____/____	Inspector _____ Date ____/____/____
Verification of skills using pre-installation test	Inspector _____ Date ____/____/____	Inspector _____ Date ____/____/____	Inspector _____ Date ____/____/____	Inspector _____ Date ____/____/____

Figure 6-2 Bolt Installer Qualification

Bolt Pre-Installation Assembly Tests

(See Section 6.6 h)

Project _____ Inspector _____

Date ____/____/____

Bolt Tension Calibrator Model _____ Number _____

Date of test ____/____/____

Test performed by _____ (Fabricator or Erector)

Bolt lot number _____

Nut lot number _____

Assembly lot number _____

Direct Tension Indicator lot number _____

Lubrication condition ☐ oily ☐ dry ☐ rusty ☐ relubricated using _____ ☐ mixed

For short bolt testing, with installation method other than turn-of-nut method:

DTI lot number _____

Measured average DTI gap at required pretension _____

Bolt Grade ☐ A325 ☐ A490

Bolt Diameter _____ Bolt Length _____

Minimum required pretension - (RCSC Specification, Table 4, following) _____ kips

Required Pre-Installation Test tension _____ kips

Installation method selected

- ☐ Turn-of-Nut
- ☐ Calibrated Wrench
- ☐ Twist-Off Type Tension Control Bolt
- ☐ Direct Tension Indicator

☐ Turn-of-Nut Method

(Performed on each lot of bolt / nut assembly at the start of the work)

- ☐ Required turns - ☐ 1/3 ☐ 1/2 ☐ 2/3
- ☐ Measured pretension _____ kips

☐ Calibrated Wrench Method

(Performed daily for each diameter, grade and lot)

- ☐ Achieved tension for wrench _____ kips
- ☐ Actual rotation _____ turn (not to exceed RCSC Specification, Table 5 rotation, following)

☐ Twist-Off Bolt Method

(Performed on each lot of bolt/nut/washer assembly at the start of the work)

- ☐ Achieved tension at twist-off _____ kips

☐ Direct Tension Indicator Method

(Performed on each lot of bolt/nut assembly with DTI at the start of the work)

Feeler gage thickness - .005 in .015 in

Pre-Installation Test Tension required _____ kips (See RCSC Specification, Table 4, following)

Actual pretension _____ kips (should equal or slightly exceed above value)

Number of feeler gage refusals _____

Number of DTI gaps	4	5	6	7	8	9
Number of refusals permitted in Pre-Installation Test	1	2	2	3	3	4
Number of refusals required for installation acceptance	2	3	3	4	4	5

Figure 6-3 Bolt Pre-Installation Assembly Tests

Bolt Pre-Installation Assembly Tests

RCSC Specification, Table 4. Fastener Tension Required for Pretensioned and Slip-Critical Connections

Bolt Diameter, d_b	Minimum Tension ^a in 1,000s of Pounds (kips)			
	A325 Bolts		A490 Bolts	
	Required Pretension	Pre-Installation Test Tension Required	Required Pretension	Pre-Installation Test Tension Required
1/2	12	13	15	16
5/8	19	20	24	25
3/4	28	29	35	37
7/8	39	41	49	51
1	51	54	64	67
1-1/8	56	59	80	84
1-1/4	71	75	102	107
1-3/8	85	89	121	127
1-1/2	103	108	148	155

RCSC Specification, Table 5. Nut Rotation from Snug Tight Condition^{a,b}

Bolt Length ^c (underside of head to end of bolt)	Disposition of Outer Face of Bolted Parts		
	Both faces normal to bolt axis	One face normal to bolt axis, other sloped not more than 1:20	Both faces sloped not more than 1:20 from normal to bolt axis
Not more than $4d_b$	1/3 turn	1/2 turn	2/3 turn
More than $4d_b$ but not more than $8d_b$	1/2 turn	2/3 turn	5/6 turn
More than $8d_b$ but not more than $2d_b$	2/3 turn	5/6 turn	1 turn

^a Nut rotation is relative to bolt regardless of the element (nut or bolt) being turned. For required nut rotations of 1/2 turn and less, the tolerance is plus or minus 30 degrees; for required nut rotations of 2/3 turn and more, the tolerance is plus or minus 45 degrees.

^b Applicable only to joints in which all material within the grip is steel.

^c When the bolt length exceeds $12d_b$, the required nut rotation shall be determined by actual testing in a suitable tension calibrator that simulates the conditions of solidly fitting steel.

Figure 6-3 Bolt Pre-Installation Assembly Tests (continued)

<h2 style="margin: 0;">Bolted Joint Inspection Record</h2> <p style="margin: 0;"><i>(See Section 6.6 i, j, k, l, m, n, o)</i></p>		
Project _____		
Inspector _____		
Date ____/____/____		
Joint: Elevation / floor _____ Grid _____		
Mark _____ to mark _____	Mark _____ to mark _____	Mark _____ to mark _____
Mark _____ to mark _____	Mark _____ to mark _____	Mark _____ to mark _____
Mark _____ to mark _____	Mark _____ to mark _____	Mark _____ to mark _____
Required installation: <input type="checkbox"/> Snug Tight <input type="checkbox"/> Pretensioned <input type="checkbox"/> Slip-Critical		
Hole condition verification: <input type="checkbox"/> No flame-cutting <input type="checkbox"/> No unfair reaming or slotting (limited to 1/32") <i>Note: Flame-cutting and unfair reaming/slotting must be reported to the Engineer for review</i> Reported ? Date ____/____/____		
Shear-Bearing Joints - Threads Excluded Condition Only <input type="checkbox"/> Proper length bolt used <input type="checkbox"/> Proper orientation of bolt		
Snug Condition Verification (no subsequent pretensioning required)		
Date ____/____/____ Inspector _____		
<input type="checkbox"/> Steel in solid contact (no gaps in vicinity of bolt holes) <input type="checkbox"/> Stick-out <input type="checkbox"/> Bolt end flush with or beyond face of nut <input type="checkbox"/> Stickout not excessive (nut has not run onto threadrunout)		
Snug Condition Verification (prior to pretensioning)		
Date ____/____/____ Inspector _____		
<input type="checkbox"/> Steel in firm contact (no gaps in vicinity of bolt holes) <input type="checkbox"/> Turn-of-Nut Method: Match-marking properly prepared (if match mark system used) <input type="checkbox"/> DTI Method: Number of DTI refusals below that required for completed installation <input type="checkbox"/> Twist-Off Bolt Method: Spline intact		
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Figure 6-4 Bolted Joint Inspection Record

Bolted Joint Inspection Record					
Pretension Verification					
Date ____/____/____		Inspector _____			
Stick-out					
<input type="checkbox"/> Bolt end flush with or beyond face of nut <input type="checkbox"/> Stickout not excessive (nut has not run onto thread runout, use matching fasteners for comparison)					
Turn-of-Nut Method (match-marked)					
<input type="checkbox"/> Rotation required 1/3 1/2 2/3 _____ Turn <input type="checkbox"/> Rotation applied 1/3 1/2 2/3 _____ Turn					
Turn-of-Nut Method (observed)					
<input type="checkbox"/> Rotation required 1/3 1/2 2/3 _____ Turn <input type="checkbox"/> Rotation applied 1/3 1/2 2/3 _____ Turn					
Calibrated Wrench Method					
Wrench calibration log number _____					
Calibration date and time ____/____/____ ____:____ am/pm					
DTI Method					
Number of DTI gaps _____					
Number of refusals required (1/2 or more) _____					
<input type="checkbox"/> Number of refusals achieved					
Twist-Off Bolt method					
<input type="checkbox"/> Spline sheared off by wrench					
For slip-critical joints only:					
<input type="checkbox"/> No paint in faying surface <input type="checkbox"/> Painted faying surface (if used) <div style="margin-left: 20px;"> <input type="checkbox"/> Approved coating type <input type="checkbox"/> Coating cured </div>					
Arbitration of Disputes					
Date ____/____/____		Inspector _____			
Reason for arbitration <i>(Note: No arbitration for Twist-Off Bolt method or DTI method)</i>					
<input type="checkbox"/> Pretensioning applied prior to verification of snug by inspector <input type="checkbox"/> Turn-of-Nut Method (match-marked) - Turns not applied or verifiable <input type="checkbox"/> Turn-of-Nut Method (observed wrench) - Wrench use not observed by installation crew <input type="checkbox"/> Calibrated Wrench <div style="margin-left: 20px;"> <input type="checkbox"/> Wrench calibration not performed <input type="checkbox"/> Wrench required recalibration </div> <input type="checkbox"/> Lubrication / condition of bolt / nut threads worse than calibrated					
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Figure 6-4 Bolted Joint Inspection Record